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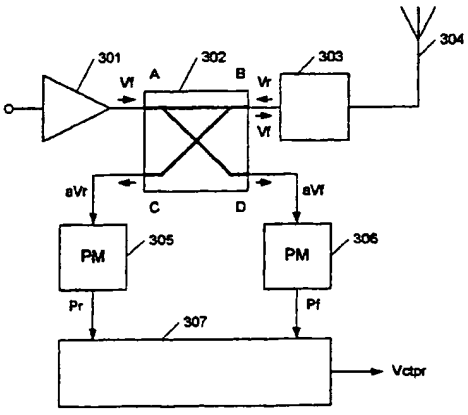
(54) Title: APPARATUS AND METHOD OF DETECTING PROXIMITY BY MEANS OF AN ANTENNA, AND CONTROLLING A LOUDSPEAKER



(57) Abstract: An electronic device (e.g. a mobile telephone) providing wireless communication, comprising: an antenna (7; 304; 404), with an impedance, to radiate an electromagnetic field at radio frequencies; a communication circuit (301; 401) connected to the antenna (7; 303; 404) to transmit and receive the communications signals; a loudspeaker (11; 603) and a proximity sensor (302, 305, 306, 307; 402, 405, 406, 407) to provide a control signal (Vctpr) indicative of whether an object (408) is in the proximity of the device. The device is characterized in that the proximity sensor is connected to the antenna (7; 303; 404) to monitor the impedance of the antenna, to modify the control signal (Vctpr) in response to changes of the impedance, and to control the volume of sound emitted by the loudspeaker (11; 603). Thereby a single antenna is used both for providing wireless communication of e.g. speech and/or data signals, while the antenna is used to sense whether an object is present in the proximity of the antenna, thereby avoiding damage to a user's hearing due to a high sound pressure. The invention also relates to a method of detecting whether an object is in the proximity of a communication device.

WO 00/79769 A1

Apparatus and method of detecting proximity by means of an antenna, and controlling a loudspeaker

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This invention relates to an electronic device providing wireless communication, comprising: an antenna, with an impedance, to radiate an electromagnetic field at radio frequencies; a communication circuit connected to the antenna to transmit and receive communication signals; a loudspeaker; and a proximity sensor to provide a control signal indicative of whether an object is in the proximity of the device.

Proximity sensors are widely used in telephones for activating various functions, for instance for switching between a handset mode and a speakerphone mode. In the handset mode a relatively small loudspeaker in the handset is switched on and used in close contact with a user's ear, whereas a larger speaker is used in the speakerphone mode allowing other persons than the speaker to listen to a telephone conversation. However, recent developments in small-sized loudspeakers for use in mobile communications devices have provided for use of high sound-pressure loudspeakers allowing the device to be used both in handset mode and speakerphone mode with a single small-sized high sound-pressure loudspeaker.

US patent No. 5,224,151 discloses a proximity sensor for use in a handset speakerphone and comprising an infrared range detection unit built into the handset for controlling switching between a handset mode and speakerphone mode.

US patent No. 5,337,353 discloses a capacitive proximity sensor comprising a guard electrode and a sensor electrode separated by an insulating layer. For example for

controlling switching between a handset mode and speaker-phone mode.

Within the field of measuring electric and magnetic variables different types of proximity sensors are disclosed.

US patent No. 5,456,405 discloses a method and an apparatus for sensing proximity of an object using near-field effects. Radio frequency energy is fed to an antenna. The antenna radiates this radio frequency energy to charge an object in the near field of the antenna. When the position of the object changes, the impedance of the antenna changes. This impedance is detected to provide an indication of the movement of the object. The sensing device may be mounted to detect the rotational velocity of a gear wheel with teeth.

However, the prior art poses the problem that the development of small-sized high sound pressure loudspeakers can lead to damages to a user's hearing if e.g. a phone is used like in handset mode, while the phone is actually in speakerphone mode. Thereby a high sound pressure may be emitted directly into a user's ear and cause damage. Further, since the small-sized loudspeakers are typically used in mobile handheld devices like for instance mobile telephones, small-sized inexpensive components is a must. Thus, since the prior art proximity sensors require expensive components specially adapted for the purpose of detecting proximity,and since such additional components require a considerable amount of space in the interior the electronic device or occupies special regions on the surface of the device, it is an object of the invention to provide an electronic device with a proximity sensor that occupies less space and can control a loudspeaker.

This is achieved when the electronic device mentioned in the opening paragraph is characterized in that the prox-

imity sensor is connected to the antenna to monitor the impedance of the antenna, to modify the control signal in response to changes of the impedance, and to control the volume of sound emitted by the loudspeaker.

Consequently, changes in response to the position of an object which interferes with the electromagnetic field in the proximity of the antenna can be detected, used to indicate proximity, and control the loudspeaker in order to avoid hearing damage to a user. The proximity sensor is very expedient in that a single antenna can be used for providing wireless communication as well as proximity detection.

Expedient embodiments of the electronic device according to the invention will appear from the dependent claims 2 through 9.

Moreover, the invention relates to a method, as stated in claim 10, of detecting whether an object is in the proximity of a communications device. Expedient embodiments of the method according to the invention will appear from the dependent claims 11-12.

The invention will be explained more fully below in connection with a preferred embodiment and with reference to the drawing in which:

fig. 1 shows an electronic device with a proximity sensor according to the invention,

fig. 2 shows a cross-sectional view through an electronic device with a proximity sensor according to the invention,

fig. 3 shows a first block diagram of a wireless communications device comprising a proximity sensor,

fig. 4 shows a second block diagram of a wireless communications device comprising a proximity sensor,

fig. 5 shows a diagram of a decision unit, and

fig. 6 shows a block diagram of a circuit for controlling a loudspeaker.

Fig. 1 shows an electronic device with a proximity sensor according to the invention. A mobile communications device 1 comprises a display 2 and a keypad 3 for operating the mobile communications device. A front cover 6 is adapted to provide access to the display, the keypad, and a loudspeaker (not shown) and a microphone (not shown). The front cover 6 comprises openings 4 and 5 for transmission of sound to/from the loudspeaker and microphone, respectively.

In order to provide wireless communication the mobile communications device comprises an antenna 7.

Fig. 2 shows a cross-sectional view through an electronic device with a proximity sensor according to the invention. The display 2, the keypad 3, a loudspeaker 11, a microphone 12, and the antenna 7 are connected to a printed circuit board (PCB) 9. The device can be operated by battery power supplied by a battery 10.

Fig. 3 shows a first block diagram of a wireless communications device comprising a proximity sensor. The device comprises a Radio Frequency power amplifier 301 adapted to amplify a communication signal Vc. The amplified communication signal Vf is supplied to a port A of a directional coupler 302. The directional coupler transmits the signal on the port A to a port B with a relatively small loss of power. The communication signal transmitted from port the A to the port B is further transmitted to an im-

pedance matching circuit 303. The impedance matching circuit 303 is responsible for matching an input impedance of the antenna 304 against the impedance of the port B or a transmission line connected between the port B of the directional coupler and the impedance matching circuit. Thereby the communication signal can be transmitted via the antenna 304 with a small loss of power. Typically, the impedance matching circuit is tuned under a special operating condition. For a hand-held mobile telephone the impedance adaptation circuit 303 is tuned to an operating condition corresponding to normal use, i.e. a situation where a user holds the phone in his hand close to his head/cheek/ear. This is preferred in order to conserve battery power and/or to provide a better transmission of the communication signal.

A part of the communication signal (Vf) supplied to the port A is transmitted to the port D of the directional coupler 302. Typically, this signal is attenuated 20-30 dB relative to the signal input on the port A. However, the power of the signal on the port D is indicative of the power of the signal on the port B. The port D is connected to a power monitor PM 306 which is adapted to measure the transmitted power of the communication signal or at least a signal indicative of the transmitted power.

When the antenna 304 is moved relative to its surroundings or, alternatively, when an object is moved within a near field of the antenna, the impedance of the antenna 304 will change, all other things being equal. Thus, when the operating conditions under which the impedance matching circuit is tuned are not present, the impedance adaptation circuit is not capable of matching the impedance between the port B of the directional coupler and the antenna 304. Thereby, the antenna will reflect a part Vr of the communication signal Vf. The signal supplied to the

antenna is denoted a forward communication signal and the reflected signal is denoted a reverse communication signal.

The directional coupler 302 provides a signal αVr at a port C indicative of the reverse communication signal Vr. Typically, αVr is attenuated 20-30 dB relative to Vr. The port C is connected to a power monitor PM 305 which is adapted to measure the transmitted power of the communication signal or at least a signal indicative of the transmitted power.

The signals Pr and Pf provided by the power monitor 305 and 306, respectively, are supplied to a decision unit 307. The decision unit 307 is capable of calculating the ratio M between Pr and Pf. That is:

$$M = Pr/Pf$$

This is the so-called Power Standing Wave Ratio (PSWR). In dependence of the value of M it is possible to determine whether an object is present in the near field of the antenna, i.e. whether an object is in the proximity of the antenna. This decision can be made by means of a threshold comparator. A typical decision criteria is that when M is relatively large, no object is present and vice versa. This is decided, having in mind that the impedance adaptation circuit is tuned as described above.

Fig. 4 shows a second block diagram of a wireless communications device comprising a proximity sensor. In this embodiment, the communications device further comprises a receiver coupled to the antenna 404 via a switch 409. The Radio Frequency power amplifier 401 is adapted to amplify a communication signal Vc and supply an amplified communication signal Vf to the antenna via the directional coupler 402, the switch 409, and the impedance matching

circuit 403. The switch is operated to switch between a transmitting mode (as shown) and a receiving mode. In receiving mode the switch is toggled to connect the antenna 404 to the receiver or preamplifier 410. The communications device is thus capable of providing wireless communication with other communication devices. The communications device is thus a so-called transceiver.

As described above, the ports C and D of the directional coupler 402 are connected to the power monitors PM 405 and 406, respectively. The decision unit 407 is adapted to calculate the ratio M:

$$M = Pr/Pf$$

Further, the decision device is adapted to provide/modify a control signal Vctpr indicative of whether an object 408 is in the proximity of the antenna 404.

When the communications device is a mobile telephone, nominal communication frequencies are 900MHz, 1800MHz, 1900 MHz, and/or 2200 GHz. In the case where the nominal communication frequency is 900MHz, the frequency band 890-915 MHz can be used for transmitting communication signals to a base station (not shown); and the frequency band 935-960 MHz can be used for receiving communication signals from the base station.

It should be noted that the directional coupler 402, the switch 409, the amplifiers 301, 401, and 401, as well as the other shown components are well-known components in the prior art.

Fig. 5 shows a diagram of a decision unit. A signal Pf proportional to the power of the forward communication signal is supplied to a voltage divider circuit with resistors R1 and R2. A circuit node connecting R1 and R2 is

connected to a non-inverting input of a comparator 501 with a Schmitt-trigger function. A signal Pr proportional to the power of the reverse communication signal is supplied to an inverting input of the comparator 501.

Fig. 6 shows a block diagram of a circuit for controlling a loudspeaker. The circuit is typically connected to a radio frequency (RF) amplifier providing a received communications signal. The RF amplifier may be the amplifier 410 shown in fig. 4 with its output connected to a terminal 604 of a demodulator 601. The demodulator 601 extracts an audio/voice signal in the received communications signal. The audio/voice signal is supplied to an audio amplifier 602 for driving a loudspeaker 603 to reproduce the audio/voice signal acoustically. In order to control the loudspeaker according to the invention, the amplifier has a gain control input terminal 605. The control signal Vctpr indicative of whether an object is in proximity of the antenna (that is, thereby, the electronic device e.g. a mobile telephone) is applied to this gain control input terminal 605. Thereby it is possible to limit the signal amplitude of the audio/voice signal supplied to the loudspeaker when e.g. a user's head is close to the loudspeaker. The volume of the loudspeaker can be controlled by limiting the amplitude of the audio/voice signal, by limiting the gain of the amplifier 602, etc.

The loudspeaker is typically a small-sized loudspeaker with a diameter less than 30 to 40 mm capable of providing a sufficiently high sound pressure to reproduce voice recognizable by a human within a radius up to about 5 metres, preferably up to 2 metres.

Generally, a handset mode is defined as a mode of operation where the loudspeaker of the device emits sound di-

rectly into a user's ear at a relatively low volume (sound pressure). A speakerphone mode is defined as a mode of operation where the loudspeaker emits sound into a space for perception by an audience at a relatively high volume (sound pressure).Although the invention has been described in connection with a mobile telephone, it may be applied in similar devices such as other communications devices, laptop computers, portable music playing devices, etc., where the detection of the proximity of an object relative to the device is of interest for the control of certain functions of the device, such as on/off-, standby/on-switching, control of display illumination, volume control of a loudspeaker, etc.

CLAIMS

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1. An electronic device providing wireless communication, comprising:

an antenna (7; 304; 404), with an impedance, to radiate an electromagnetic field at radio frequencies;

a communication circuit (301; 401) connected to the antenna (7; 303; 404) to transmit and receive communication signals;

a loudspeaker (11;603);

a proximity sensor (302, 305, 306, 307; 402, 405, 406, 407) to provide a control signal (Vctpr) indicative of whether an object (408) is in the proximity of the device;

characterized in that

the proximity sensor is connected to the antenna (7; 303; 404) to monitor the impedance of the antenna, to modify the control signal (Vctpr) in response to changes of the impedance, and to control the volume of sound emitted by the loudspeaker (11;603).

2. An electronic device according to claim 1, characterized in that the communication circuit (401) comprises a switch (409) for toggling between receiving communication signals from the antenna (7; 304; 404) and transmitting communication signals to the antenna.

3. An electronic device according to claims 1-2, characterized in that the communication circuit (301;401) is connected to the antenna (7; 304; 404) by means of a directional coupler (302; 402).

4. An electronic device according to claims 1-3, characterized in that the proximity sensor is connected to the antenna (7; 304; 404) by means of a directional coupler (302; 402).

5. An electronic device according to claims 1-4, characterized in that the proximity sensor comprises a power monitor (306; 406) adapted to measure power forwarded to the antenna (7; 304; 404).

6. An electronic device according to claims 1-5, characterized in that the proximity sensor comprises a power monitor (305; 405) adapted to measure power reflected from the antenna (7; 304; 404).

7. An electronic device according to claims 1-6, characterized in that the proximity sensor comprises a decision circuit (307; 407; R1, R2, 301) adapted to compare power forwarded to the antenna and power reflected from the antenna, in response to the power forwarded to the antenna.

8. An electronic device according to claims 1-7, characterized in that the device comprises means (602) for controlling the volume of sound emitted by the loudspeaker (603) in response to the control signal (Vctpr).

9. An electronic device according to claims 1-8, characterized in that the loudspeaker is a loudspeaker with a handset mode of operation and a speaker mode of operation.10. An electronic device according to claims 1-9, characterized in that the device is a mobile telephone (1).

10. A method of detecting whether an object is in the proximity of a communications device, comprising the steps of:

supplying a communication signal to an antenna;

providing a first signal representative of the power of the communication signal;

providing a second signal representative of power reflected from the antenna;

characterized by the steps of:

providing a control signal responsive to the first signal and the second signal and indicative of whether an object is in the proximity of a communication device; and

controlling a loudspeaker in response to the control signal.

11. A method according to claim 11, further comprising the step of: calculating a ratio between the first signal and the second signal.

12. A method according to claims 11-12, further comprising the step of: receiving a communication signal from the antenna.

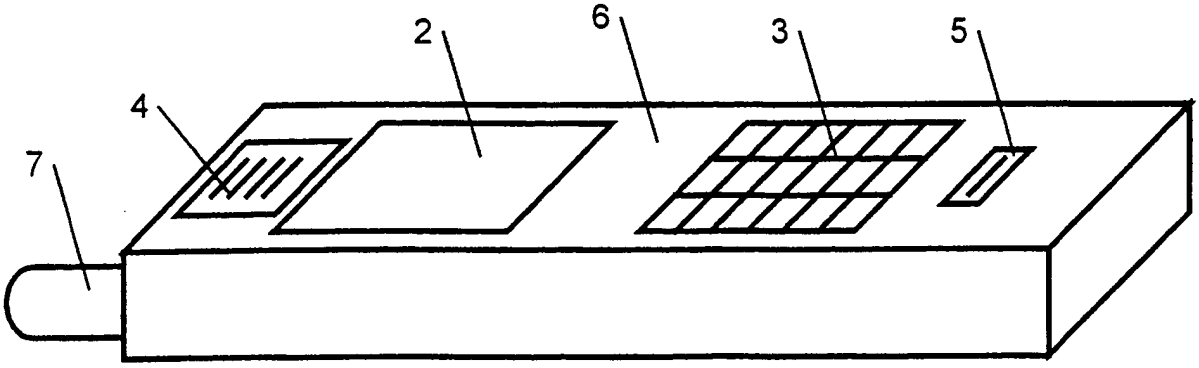


Fig. 1

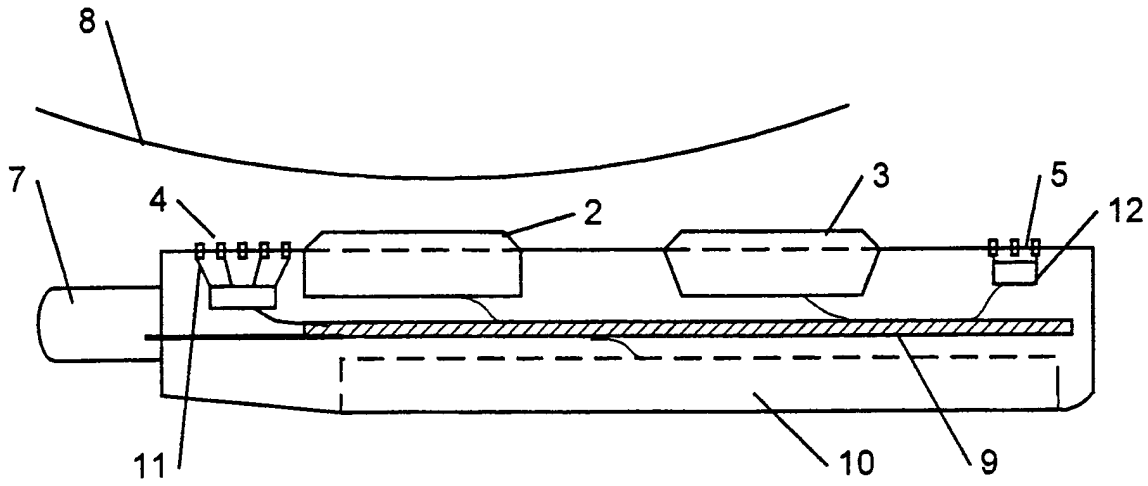


Fig. 2

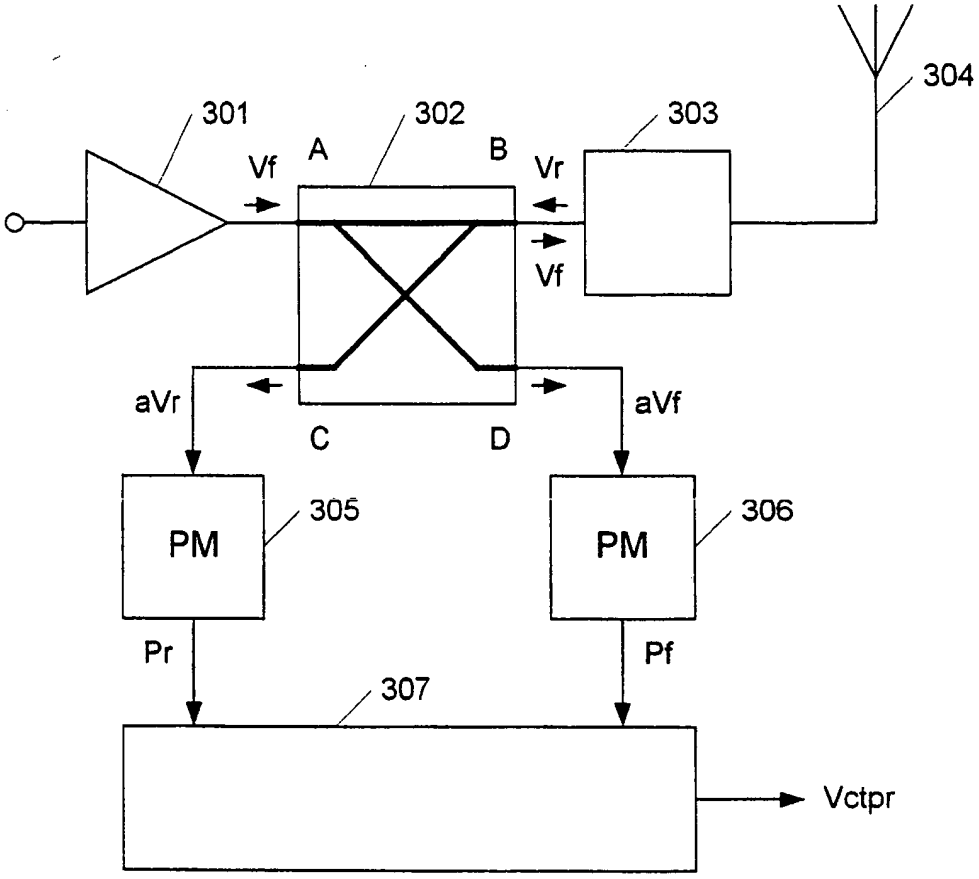
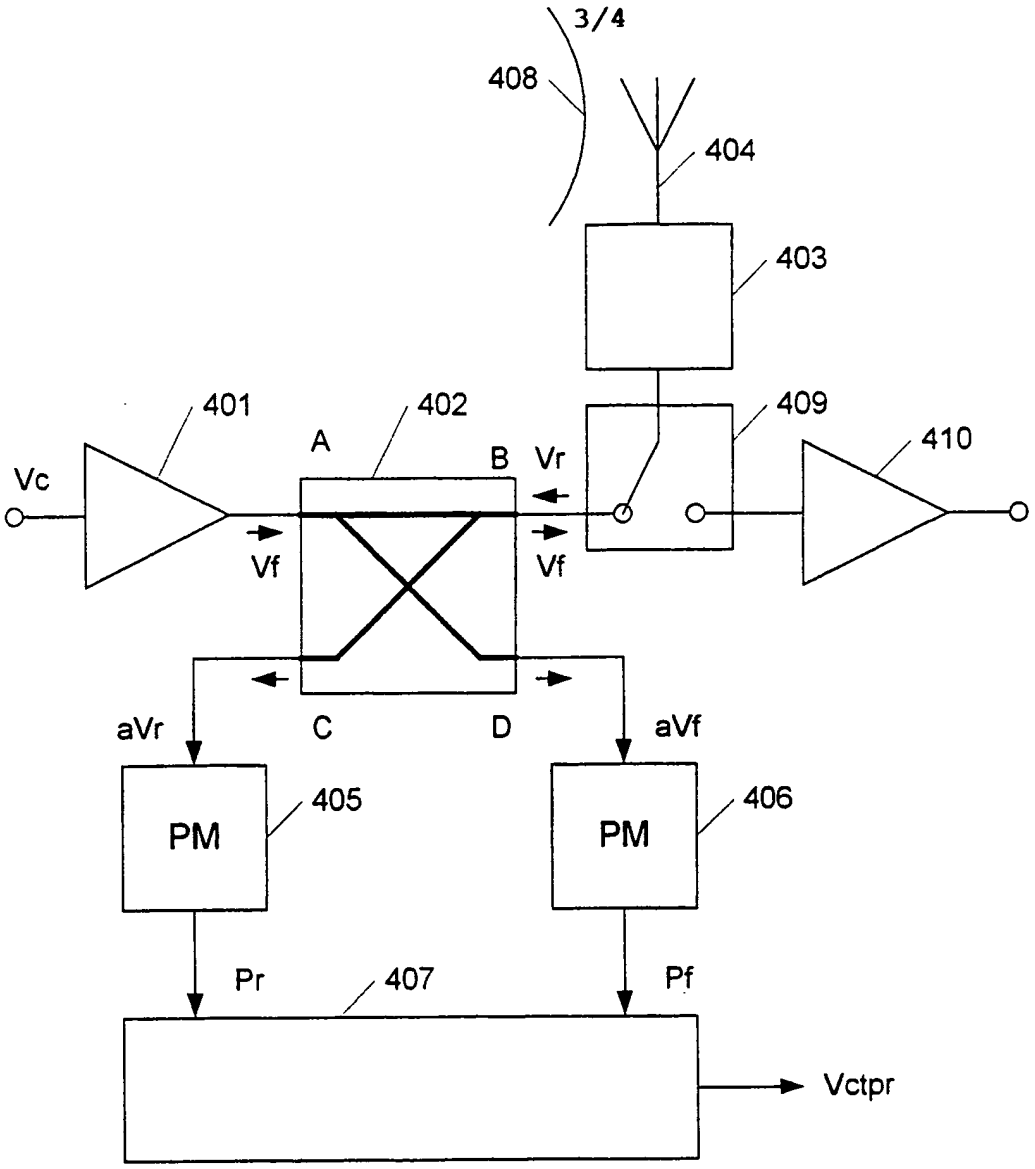

301
302
303
304
Vf
A
B
Vr
Vf
aVr
aVf
C
D
PM
305
PM
306
Pr
Pf
307
Vctpr

Fig. 3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404
403
401
402
409
410
A
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Vr
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D
aVr
aVf
PM
405
PM
406
Pr
407
Pf
Vctpr

Fig. 4

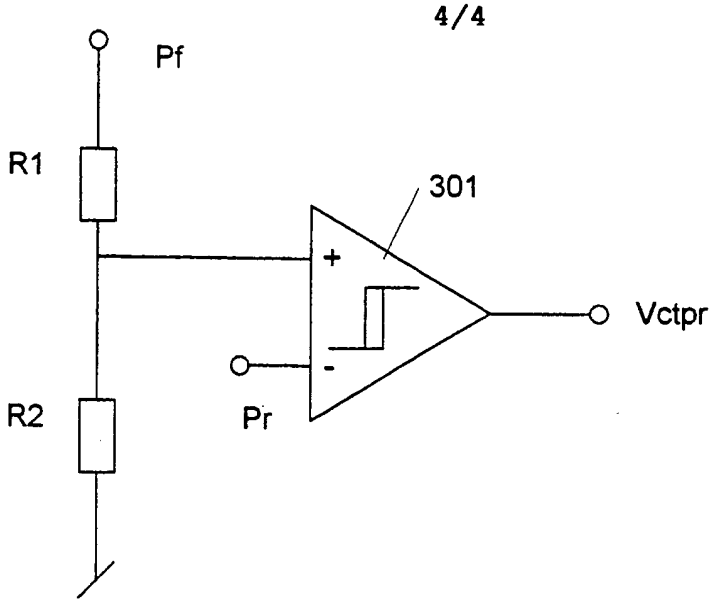
Pf
R1
301
+
-
Vctpr
R2
Pr

Fig. 5

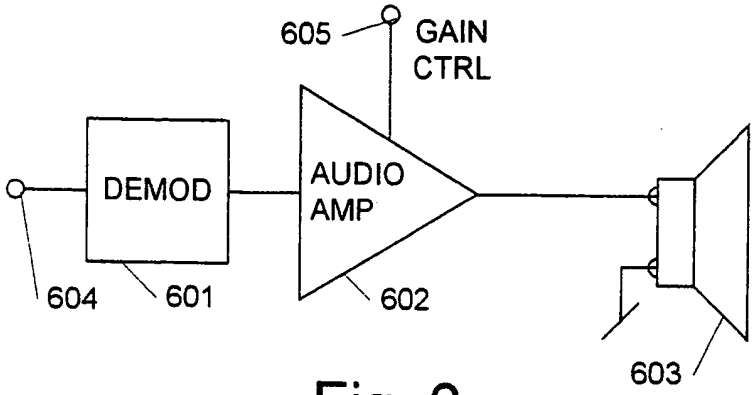
605
GAIN
CTRL
DEMOD
AUDIO
AMP
604
601
602
603

Fig. 6

INTERNATIONAL SEARCH REPORT

International application No.
PCT/SE 00/01324

A. CLASSIFICATION OF SUBJECT MATTER

IPC7: H04M 1/00
According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

IPC7: H03K, H04B, H04M, H04Q

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

SE,DK,FI,NO classes as above

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	EP 0827287 A2 (NOKIA MOBILE PHONES LTD.), 4 March 1998 (04.03.98), column 4, line 42 - line 50, abstract ---	1-13
Y	US 5224151 A (D.J. BOWEN ET AL.), 29 June 1993 (29.06.93), column 2, line 10 - column 6, line 31, figures 1-10, abstract --- --------	1-13

☐ Further documents are listed in the continuation of Box C. ☒ See patent family annex.

* Special categories of cited documents:
"A" document defining the general state of the art which is not considered to be of particular relevance
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"X" document of particular relevance: the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
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"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
17 August 2000	22 -09- 2000
Name and mailing address of the ISA/ Swedish Patent Office Box 5055, S-102 42 STOCKHOLM Facsimile No. +46 8 666 02 86	Authorized officer Roland Landström/AE Telephone No. +46 8 782 25 00

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No.
PCT/SE 00/01324

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
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